European Online Journal of Natural and Social Sciences 2015;
Vol.4, No.1 pp. 130-141
ISSN 1805-3602
www.european-science.com

A Study of Methods of Utilizing Sunlight for Creation of Thermal Comfort in Residential Settlements of Tabriz

Behzad Hatefi*, AmirHossein FarahiNia
Department of Architecture, college of Arts and Architecture, Shabestar Branch, Islamic Azad University, Shabestar, Iran.
* E-mail: behzad.hatefi67@gmail.com

Received for publication: 06 October 2014.
Accepted for publication: 15 February 2015.

Abstract

Iran has different climatic characteristics one of which is dry and cold climate in North West regions of Iran. Therefore, it is evident that these regions have a significant share in national energy consumption to provide heating for buildings. The bases of this paper are qualitative library studies, existing books and papers in this regard and it is in descriptive and analytic method. In the present paper, the researcher attempted to introduce different passive solar systems (indirect absorption method) and their usage in the climate of Tabriz in a schematic manner and from different perspectives to provide the basis for sustainable development in large scale. It endeavored to clarify different aspects of using these solutions and to spread out the usage of aforementioned systems which might finally lead to development of sustainable architecture in Tabriz.
Keywords: Passive Solar Systems, Solar Energy, Tabriz, Sustainable Architecture

Introduction

Undoubtedly, sun is the source of life on Earth which provides us with its sunlight. A little thought would make one understand that in addition to energy-issuing sunlight, there are other energies of solar origins which human beings use. However, different studies have confirmed the fact that in average, sun radiates 1.1 x 10^{20} kilowatt energy per second. Of this energy, only 47 percent gets to the surface of the Earth. This means that in an hour, the Earth absorbs 6 million Btu per hour (Iranian Fuel Conservation Company, 2014).

Solar energy is regarded as one of the best renewable energies in the world and necessity of using this unending source is more highlighted daily. Iran is located in the war global belt so that it absorbs relatively high solar energy. Iran is located in 25 to 40 degrees of the northern latitude within a region in which highest rates of absorbing solar energy exists. The value of solar radiation in Iran is estimated between 1800 and 220 kilowatts per hour per year which is higher than annual mean (Iranian Fuel Conservation Company, 2014). This issue shows that Iran has a high capacity in using solar energy, especially in desert areas.

Based on the reports of U.S Energy Information Administration (EIA) and World Health Organization, Iran has the tenth top position in producing greenhouse gases and eighth position of air pollution in the world. A major part of this energy is consumed not in industrial production but in construction and creation of proper conditions and comfort inside the building. At the present moment, about 40 percent of the total energy consumption in Iran is done in residential and business sections which is due to improper design of cities and buildings (Mardom-Sallary Newspaper, 2014). The energy consumption in the buildings is equal with 30 percent of annual petroleum income which is 15 billion dollars in 2005 of which 50 percent is wasted. Usage and waste of energy lead to increase of energy consumption to provide air conditioning in buildings which causes an increase in production of greenhouse gases and increase of global warming (Second Symposium on Energy Conservation in Buildings, 2003).

Based on these descriptions, the building design becomes more significant in the present world and evaluation of thermal behavior of buildings and creation of comfort condition in the internal space by maximum utilization of climate elements becomes an inevitable element.

Definitions

Using climatic techniques to prevent significant increase of global warming and to reduce the consumption of energy sources, one has to identify climatic elements and elements of the region so that techniques of climatic criteria have maximum efficiency. First, some concepts such as climate, climate design, sustainable development and sustainable architecture are reviewed which will be alluded to later.

Climate

In short, climate is the long-term weather of the region which means stable climate state of an area.

Climate Design

Climate design refers to a design in which coordination with surrounding environment and more usage of existing natural force of the location are accompanied with provision of proper natural environment for users (Kasmaii, 1991).

The term “implementation of climate design” refers to special construction methods the aim of which is reduction of heating and cooling costs by using natural energy flows to create convenience in buildings (Ghobadian and Feiz Mahdavi, 2002).

Sustainable Development

In early 1970s, the term “Sustainable Development” was first used for environment and development. Since then, this name and characteristic of international organizations which seek achievement of proper development environment made the term “Sustainable Development” common among scientific communities, especially after Rio de Janeiro’s conference in 1992 (Zarabi and Ezati, 2002).

Sustainable development seeks to satisfy the following five basic demands:

- Admixture of Protection and Development
- Satisfaction of Basic Biological Needs
- Achievement to Social Justice
- Autonomy and Cultural Diversity
- Maintenance of Ecological Uniqueness (Gorji Mahlebani, 2011)

Sustainable Architecture

Today, the term “sustainable architecture” is used for a wide range of approaches of environmental sensitivity from traditional architecture which are regarded as the architecture with an approach of ecological and social sustainability to approaches with claims for more stabilization of existing architecture that seeks maintaining a distinctive style and entering an aspect of environmental sensitivity into the appearance of design or environmental applications (Asadpur, 2007).

Climatic Characteristics of Tabriz

Iran is divided into 4 climatic regions:

- Dry and Warm
- Dry and Humid
- Humid and Mild
- Dry and Cold (Shakibamanesh and Mahmoodi, 2011).

Western mountains which include western slopes of central mountain chains of Iran, due to the fact that mean temperature in the hottest month of the year is more than 10 and average temperature in the coldest month is less than -3 degrees, are among cold areas (Kasmaii, 2006). So, Tabriz is regarded among cold and dry regions. Western mountain chains act as a bar against intrusion of Mediterranean humid air into the plateau of Iran and maintain air humidity in its slopes. Of the characteristics of this climate, one can point to severe heat in vales during summer and mild weather during winter. The value and intensity of solar radiation in this region are high in the summer while it is very low in winter. Winters are long, cold and fierce. Few months of the year is accompanied by ground coverage by ice. In the whole region, from Azerbaijan to Fars, winters are highly cold, the coldness starts from early November and it continues till late April. Rainfall is low in summer and high in winter, mostly in snow. Consecutive snow falls cover most of the mountain tops and it often snows in high lands with altitude of more than 3000 meters. In general, spring is short in this region and it separates winter and summer (Kasmaii, 2006).

With above descriptions and in most months of the year, Tabriz is cold and tools and equipment should be used to provide comfort. Therefore, high consumption of petroleum products is inevitable in this region unless a climatic design with the approach of sustainable architecture becomes the basis of our design and cooling-heating systems with renewable motion forces are used. One of the best options for a climate with these conditions is using solar systems.

Solar Systems

Solar systems are used in two ways: active and passive. Each category has its application and characteristics which if designed properly and after necessary analyses, it can play a significant role in reduction of fuel energy consumption of the buildings and sustainability approach.

Passive Solar Systems

Passive solar systems refer to those in which solar energy is collected and saved without using energy-consuming devices such as pump or controller. By applying this method, different parts of the building can satisfy expectations of architecture, static parameter and safety as well as optimization of energy consumption and reduction of running and equipment costs as primary priorities of design,. These systems are among the most efficient one (Lekner, 2007).

Passive solar systems are divided into 3 categories based on their performance:

1- Direct Gain
2- Indirect Gain
3- Isolated Gain (Roaf, 2007, p. 178)

The present paper investigates the indirect gain method.

This method is divided into three parts:

1- Heat Wall or Trombe
2- Roof Pond
3- Solar Greenhouse

In the following, different kinds of passive solar methods are introduced based on climate of Tabriz.

Heat Wall or Trombe Wall

In this system, thermal mass (i.e. wall) is located behind glass of southern side.

In this method, a normal wall is used beside a glass with the following conditions:

1- The wall should face sun and made of materials of high thermal capacity. Its thickness should be 0.3-0.45 meter for concrete walls, 0.25-0.35 meter for block walls and 0.2-0.3 meter for clay walls or those made by other materials.

2- The wall has single-directional and light hatches in top and bottom (the total area of the hatches is 1/100 of the wall area).

3- The hatches are open during day and close during the night.

4- The southern wall of the building should have a dark color to maximize light and heat absorption.

5- The glass can be single-walled or double-walled. It is better to be double-walled to prevent energy waste.

6- Minimum difference between glass and wall is 0.1 meter and 0.7 meter is recommended for possibility of cleaning.

7- In a space of 0.7 meter, one can use water as thermal mass to save energy during the day.

8- Using night insulation (dark-colored thick blind) is recommended to prevent energy waste during night.

Thermal Performance of Trombe Wall

To create heating in cold seasons, internal space is warmed by displacement of air flow through hatches of controlling air flow during day and radiation of internal wall during night. Therefore, this kind of wall warms the space in all cold seasons and 24-hour of the day in cold seasons. Hatches open during day and out of lower hatch, the cold air of the room enters the space between Trombe walls and glass and then rises after heating. Then the hot air enters the room from top hatch. In this manner, the room air becomes hot during the day and bottom and top hatches are closed to heat the space. Trombe wall releases the absorbed wall during day into the space and through radiation (Farokhi, 2013; figure.1).

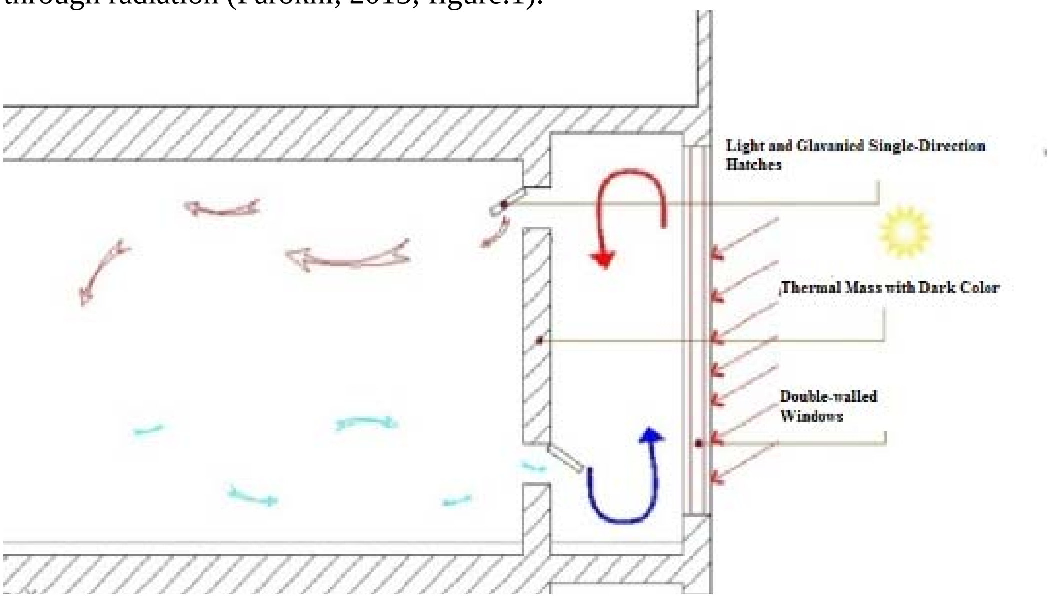

Figure 1.Trombe Wall, heating in winter

Cooling Performance of Trombe Wall

In hot seasons of the year, installation of the a window in the northern part of the building exposed to North cool winds and exposing Trombe wall in southern side of the building are the necessity of this type of static cooling. It should be noted that to generate cooling and air-conditioning, the top hatch of Trombe wall should be closed while the lower one is open. In addition, to provide air exit, creating a hatch in the external part of Trombe system at the top of the glass (output hatch below the roof) is necessary. Due to difference of temperature in northern and southern frontlines, a suction is done in the space of interior air. It enters the cool air from northern window and so, after cooling the internal space, it is directed towards bottom hatch of Trombe wall. Air flow becomes hot in the space between wall and glass, rises and exits the top hatch of external glass (figure.2).

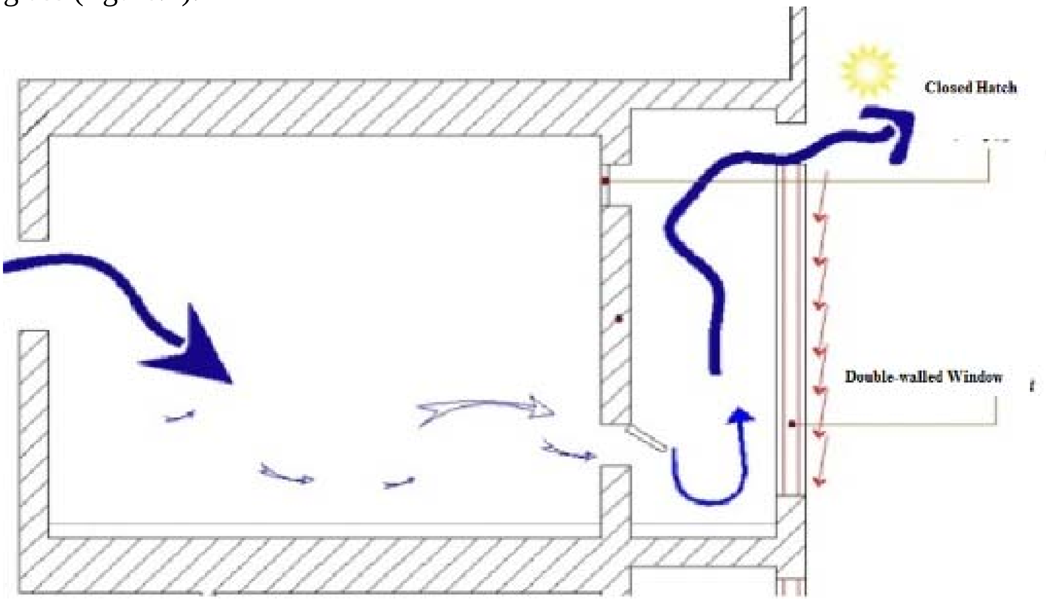

Figure 2.Trombe Wall, cooling at summer

Advantages and Disadvantages

Simplicity, low-cost maintenance and easy implementation of this system are significant characteristics of Trombe wall. This wall works properly in winter due to insulated space between outdoor space and inside the room. This wall has long endurance, low initial cost and ability of execution by the public. Using existing local materials, lack of using electrical devices, lack of noise and economic efficiency and high ability to save energy and reduce fuel consumption are the other advantages of this wall. Of disadvantages of this system, on can refer to dependence on natural conditioning to perform cooling in summer, lack of using carpet in heat floors, prevention from entering light of south into the building, darkness and the so-called depressing space as well as lack of outward view.

If the natural light is not provided from other sides, the value of electric energy consumption will be more to provide the necessary light. It should be noted that using large walls facilitates background view and light but the area of Trombe wall becomes less.

Roof Pond System

In this system, natural cooling and heating is done by saving a definite value of water in clear bags on a black metal surface. In this system, an aluminum layer covers the water bags the lower part of which is insulated. This demands flatness of the roof and it is suitable for regions with low humidity and high temperature variance. This method is not recommended for areas of low humidity and coldness with high temperature variance. This method is not recommended for humid regions and it is not proper for hot and dry regions. So, Tabriz has the potential of using this simple and easy method.

Performance analysis of this system in two hot and cold seasons of the year during night and day in Tabriz is provided in the following sections.

Summer-Day

Roof in summer receives more energy compared with other surfaces of the building due to more vertical radiation. At the time in which there is no need for absorption of solar energy, accordion aluminum layers spread out to cause sunlight radiation. This provides a shadow on the roof and cools it. On the other hand, the interior air of the building moves towards the top due to lightness. Because of the temperature difference in both sides of the roof, heating is absorbed by water bags through conduction and convection. In this manner, interior heating of the building exits and temperature reduces (figure.3).

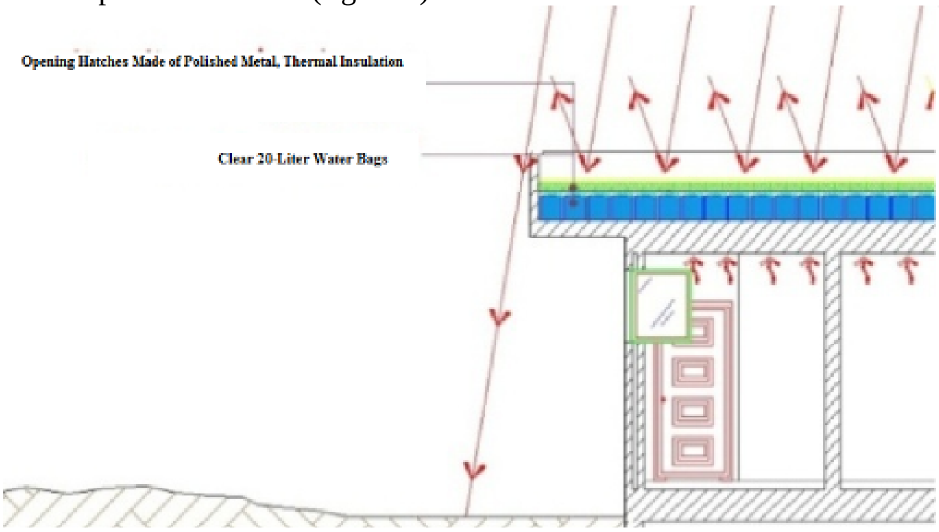

Figure 3.Roof Pond, Summer-Day

Summer-Night

As observed above, the heat inside the building is transferred to water bags during day. To dispose the heat from water bags, aluminum layers shrink at night so that cooler airflow can absop the heat of water bags during contact. This cools the water and prepares water bags for the next day (figure.4).

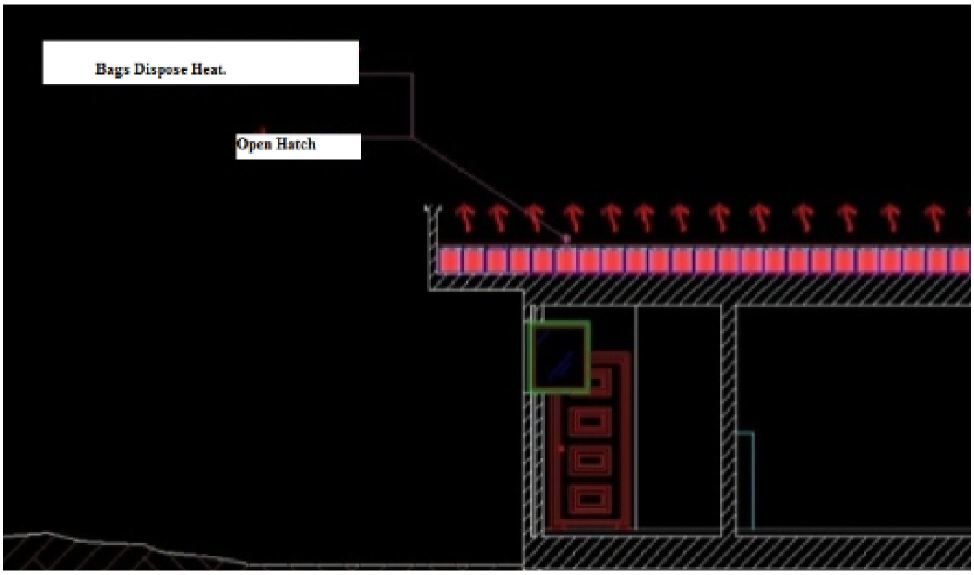

Figure 4.Roof Pond, Summer-Night

Winter-Day

In a winter day, there is need to absorb maximum solar energy. To do this, aluminum layers shrink to save solar energy during direct contact with water bags. Also, hot water bags with black metal layer on the roof maximize solar energy absorption and lead to maximization of the difference between two sides of the roof. As a result, the wasted heart of the roof reduces during the day (figure.5).

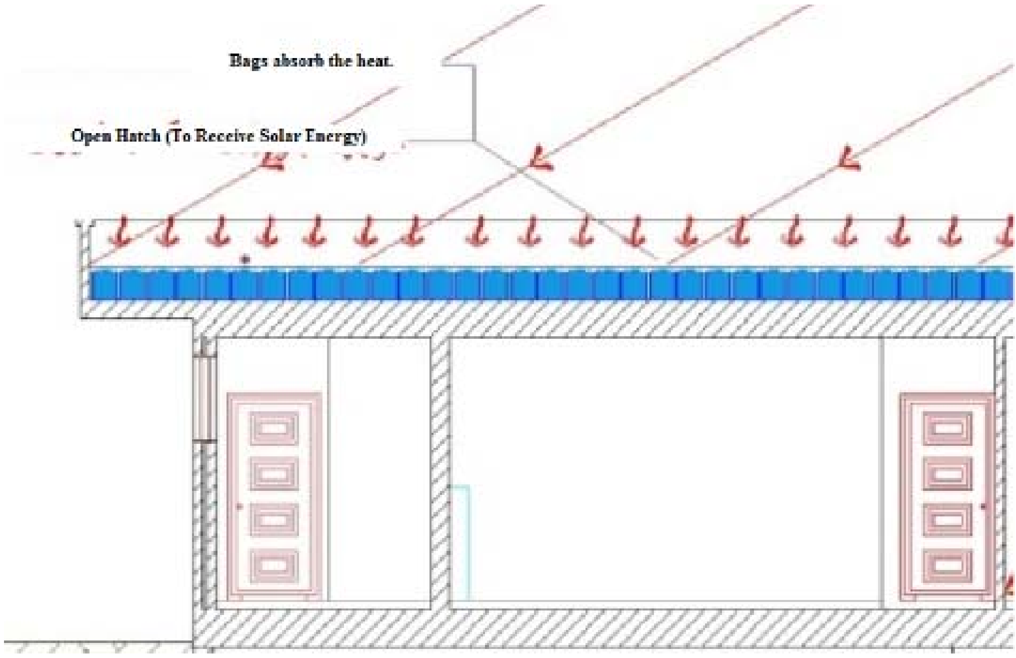

Figure 5. Roof Pond, Winter- Day

Winter-Night

In winter night, the exterior air of the building is colder than interior one. Therefore, the heat intends to exist the building. To prevent this issue, aluminum layers should spread so that heated water bags during the day don't lose their heat due to exterior cold air. Therefore, the water heat crosses the roof through conduction and gets to the interior space of the building. In this way, waste of heating from the roof is prevented and this causes heating of interior of the building (figure.6).

Advantages and Disadvantages

Of the disadvantages of this system, one can point to increase of dead load of the building and necessity of its prediction in the process of design and calculation. This system only serves the bottom floor and during winter days, no shadow should fall on roof so as not to prevent the heating of thermal mass (water). One of the advantages of this method is its heating and cooling functions which means its application during the year. By using this method, severe variance of temperature is very low in the interior and due to wide radiation area (usually all the roof), very proper heating quality is made.

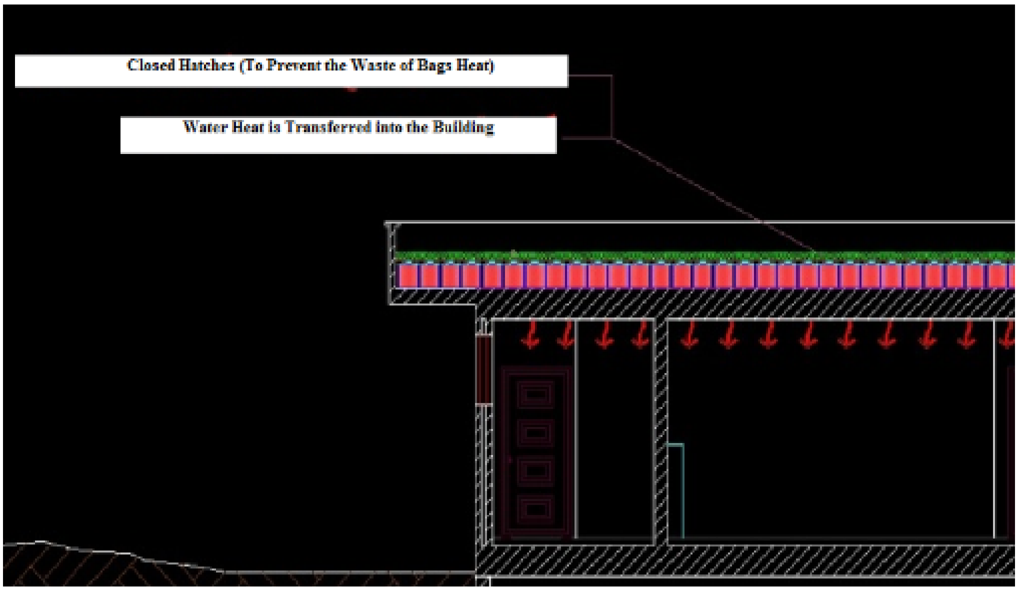

Figure 6. Roof Top, Winter- Night

Greenhouse and Stone Pit

This method is one of the common static systems and it includes an insulated space by glass in the southern side of the building to maximize sunlight usage. Greenhouse acts as the collector of solar energy during the day and releases this energy during the night. In summer, it cools the air which flows from the exterior of the building into it. Heat transfer from solar greenhouse to surrounding area can be done by a common wall through directing, radiation or openings inside of common wall (Fuller, 1993). In this method, heat transfer is done naturally and artificially (i.e. by mechanical devices).

Designing solar greenhouse and its precise shape are different based on diverse climates. Here, the author seeks to introduce a solar greenhouse matching the climate of Tabriz.

Sand is one of the local materials of Tabriz which due to molecular density and heavy mass, it has a proper thermal capacity. This means that it can absorb thermal energy and save it. It can be used as thermal mass in cold climate of Tabriz in a greenhouse system.

In the following sections, a greenhouse system with stone pit is analyzed in four different times of Tabriz climate (summer day, summer night, winter day and winter night).

Summer-Day

As it can be easily observed, stone pit hatches are completely closed in summer day because there is no need to save energy in summer. The greenhouse roof acts as a shade and prevents the intrusion of sunlight into the room. The windows are open so as not to trap the solar heat. In greenhouse space, greenhouse plants can be used to modify, cool and humidity the proper passing air flow from exterior into the interior of the building (figure.7).

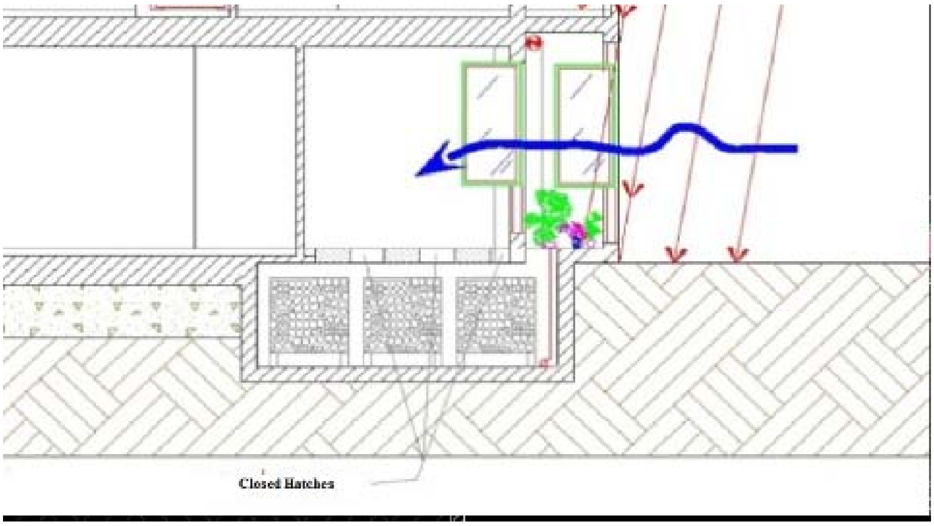

Figure 7.Greenhouse and Stone Pit, Summer-Day

Summer-Night

In summer night, the stone pit doesn’t function too. The hatches are open and windows are open for proper conditioning. As evident, greenhouse system has the least performance during summer (figure.8).

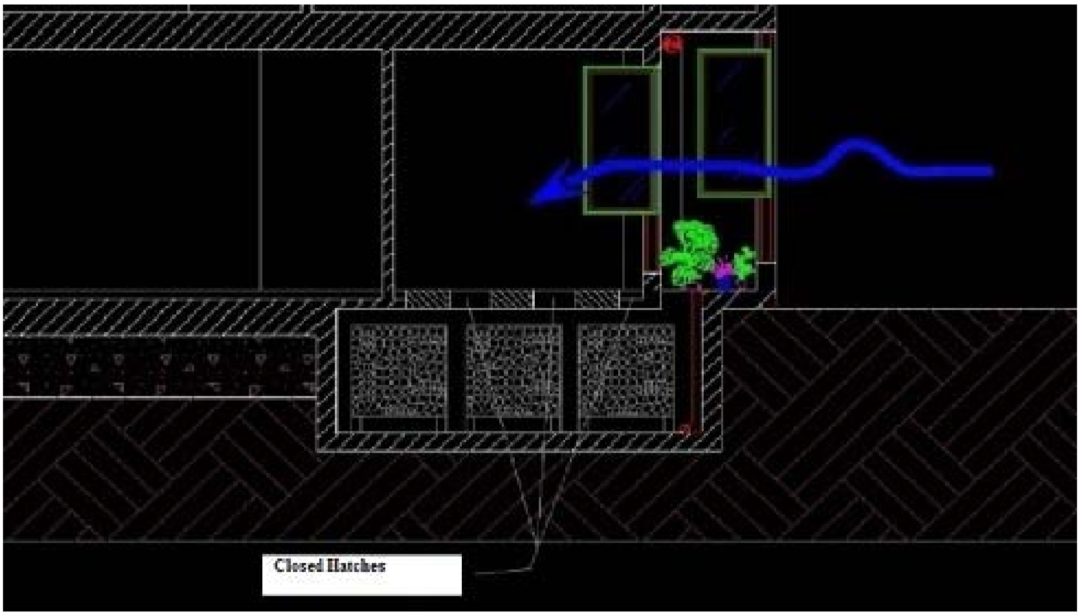

Figure 8.Greenhouse and Stone Pit, Summer-Night

Winter-Day

During winter, sun radiates in a more inclined manner compared with summer. Therefore, the light enters the roof and radiates over the floor and heat wall inside the room which are made of materials of high thermal capacity. Inside the roof, water can be used to save energy. Wavelengths of sun beams also increases after crossing the exterior side of building glass which is entrapped inside the greenhouse space after conversion to thermal energy. This causes increase of temperature in greenhouse. The hot air moves upward in which the hot air is directed towards the stone pit inside the ground by the installed fan and duct. The sand is put insides boxes with dimensions of 1x1x1 meter and 0.2 meter distance from every side. Hot air cools after thermal exchange with stones through convection and then, it moves towards the lower part of the stone pit. In lower part, the air is restored to the greenhouse by fan and duct so as that air can become warm and process can be continued. During day, the thermal energy is saved in grand grains and entrapped air between the stones. The hatches inside the room are certainly closed (figure.9).

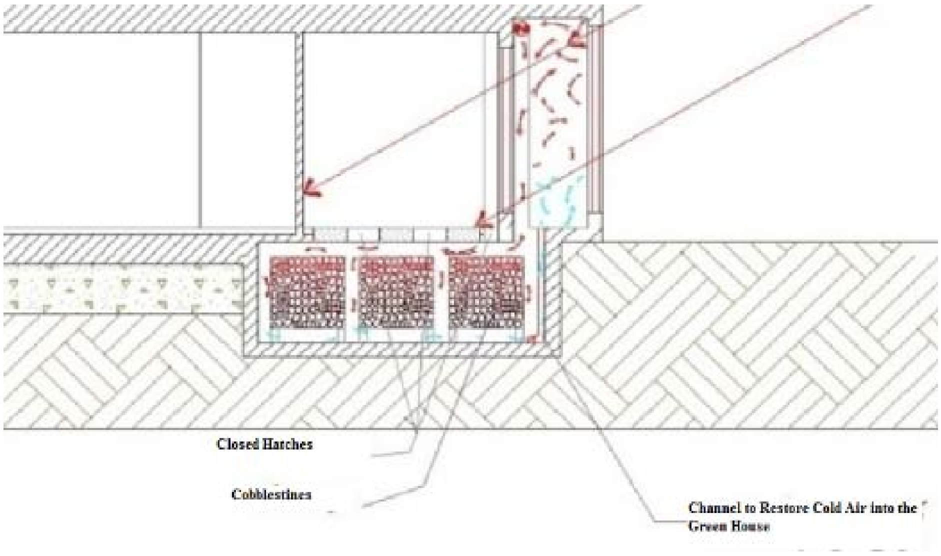

Figure 9. Greenhouse and Stone-Pit, Winter-Day

Winter, Night

During the night, the fan inside the greenhouse is turned off and installed hatches in the floor open.

The energy saved during the day is released without using mechanical and electrical devices. Because the thermal capacity of sand is high, the heat is gradually released during night and this leads to proper heating during the night. By creation of proper insulated ducts, this energy can also be used in higher floors. Covering by movable night insulation (thick blind) prevents from transfer of heat to building exterior. Double-walled window and entrapped air in greenhouse space act as insulation and they significantly contribute to maintaining energy and maximization of thermal exchange in the building (figure.10).

Advantages and Disadvantages

The wall between greenhouse and living room should be made of materials of high thermal capacity but there is more freedom in selection of other materials. By proper design, all radiations inside the greenhouse change into heat and cause increase of efficiency. As a result, the transferred heat into the rooms also increases. This system is mostly used to generate heating during winter but during summer, the installed windows in greenhouse space should be open to cause so as not to increase building temperature and to facilitate conditioning function. Using mechanical devices to direct air flow from greenhouse to stone pit and in reverse direction is one of the significant points of this system.

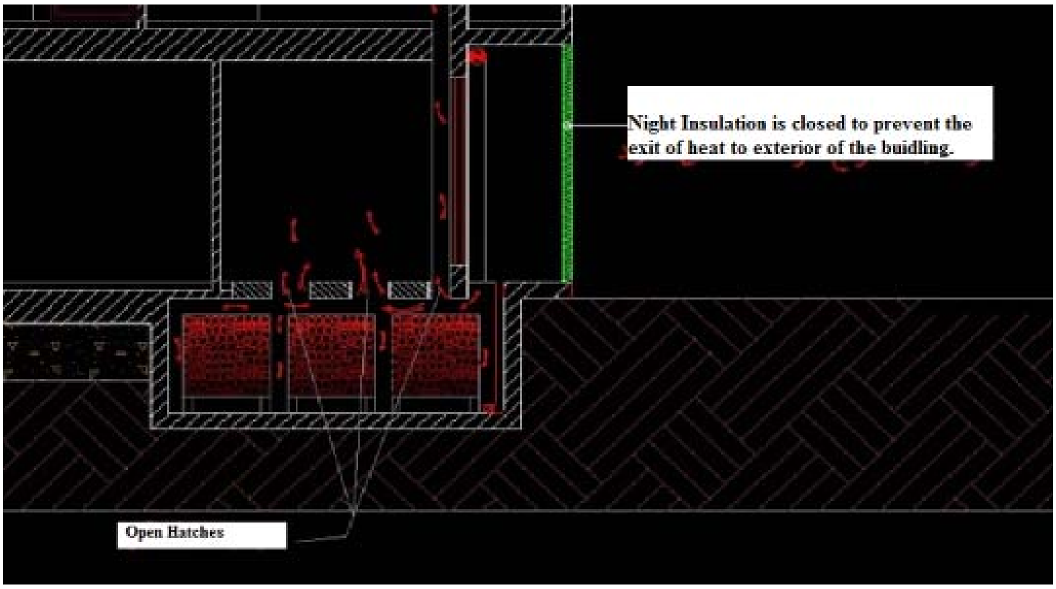

Figure 10. Greenhouse and Stone Pit, Winter-Night

Conclusion

In buildings, there are various methods to optimize the consumption of fuel energy three of which were reviewed in the present paper. The studies show that these methods can be executed in Tabriz weather and can play a significant role in reduction of fuel consumption. Low initial cost, less need for skill and knowledge during installation, high efficiency and using local materials in these methods make it possible to use them for all social strata. In this regard, this ambiguity might rise that why, despite of significant features, the public doesn't favor these methods? The author believes that a part of the answer is related to lack of public awareness of these methods and governmental support of solar building owners by loans to provide necessary drive for increasing usage of these methods and to develop the objectives of sustainable development.

References

Asadpur, A. (2007). Sustainable Patterns in Desert Architecture of Iran, Regional Scientific Conference of Desert Architecture. Ardestan.

Farokhi, B. (2013). Introduction of Trombe Walls and Solar Water Heating Panels in Construction Industry with Objective of Gaining New Energies. Second Conference of Environmental Planning and Management.Tehran University.

Fuller, M. (1993). Environmental Control Systems: Heating, Cooling, Lighting. New York: McGraw-HillIn.

Ghobadian. V, Feiz Mahdavi, M. (2002). Climatic Design. Tehran: Tehran University Press.

Gorji Mahlabani, Y. (2011). Sustainable Architecture and its Criticism in Domain of Environment. Scientific-Research Publication of Scientific, Architecture and Urban Construction Forum of Iran, No.1, pp. 91-100.

Lechner, Norbert (2007), Heating, Cooling, Lighting: Design Methods for Architects. Canada: Simultaneously in Canada publication.

Kasmaii, Mortaza (2006). Climate and Architecture. Isfahan, Khak Press.

Kasmaii, Morteza (1991). Climate and Architecture of Khozestan,-Khoramshahr. 1st Edition, Tehran. Construction and Settlement Research Center Press.

Report of Second Conference of Fuel Consumption in Building. (2003).Tehran.

Roaf S, Fuentes M, And Thomas S, (2007) Eco house, A Design Guide, Third Edition, oxford, UK.

Shakiba Manesh, A and Mahmoodi, K. (2011). Regulation of Regional Conditions. vol. 2.Tehran: Tahan Press.

Website of Hamshahri Newspaper-[http://mardomsalari.com/template1/News.aspx?NID=184226, accessed in 2014/06/26]

Website of Iranian Fuel Conservation Company- [http://ifco.ir/building/renew/sun.asp, accessed in 2014/06/24]

Zarabi, A, Azati M. (2002). Meaning and Significance of Sustainable Development in Industrial and Developing Worlds. Progress of Geography Education Magazine, 59.